CLAIMS

I/We claim:

1. Apparatus for interrogating a sample that exhibits low-frequency molecular motion, comprising:

a container adapted for receiving the sample, the container having both magnetic and electromagnetic shielding;

an adjustable-power source of Gaussian noise for directing Gaussian noise to the sample, with the sample in the container;

a detector for detecting an electromagnetic time-domain signal composed of sample source radiation superimposed with the directed Gaussian noise; and

an electronic computer adapted to receive the time-domain signal from the detector, and to process the signal to generate a spectral plot that displays, at a selected power setting of the Gaussian noise source, low-frequency spectral components characteristic of the sample in a selected frequency range between DC and 50 kHz.

2. The apparatus of claim 1, wherein the electronic computer includes a signal analyzer that functions to (i) calculate a series of Fourier spectra of the time-domain signal over each of a plurality of defined time periods, in a selected frequency range between 100 Hz and 50 kHz, and (ii) average the Fourier spectra.

3. The apparatus of claim 2, wherein the calculating includes calculating at least five Fourier spectra, each taken over a 1-5 second time-domain interval.

4. The apparatus of claim 1, wherein the electronic computer includes machine readable code operable to:

(i) store the time-domain signal of the sample over a sample-duration time T;

(ii) select a sampling rate F for sampling the time domain signal, where F* T is a total sample count S, F is approximately twice a frequency

domain resolution f of a Real Fast Fourier Transform of the time-domain signal sampled at sampling rate F, and S>f * n, where n is at least 10,

(iii) select S/n samples from the stored time domain signal and perform a Real Fast Fourier Transform (RFFT) on the selected samples to produce an RFFT signal,

(iv) normalize the RFFT signal and calculate an average power for the RFFT signal,

(v) place an event count in each of f selected-frequency event bins where a measured power at a corresponding selected frequency is greater than an average power times a value ε, where 0< ε<1 and is chosen such that a total number of counts placed in an event bin is between about 20-50% of a maximum possible bin counts in that bin,

(vi) repeat steps (iii-v), and

(viii) generate a histogram that shows, for each event bin f over a selected frequency range, a number of event counts in each bin.

5. The apparatus of claim 4, wherein the machine readable code is further operable to, in (iv), place the normalized power value from the RFFT signal in f corresponding-frequency power bins, and in (viii), (a) divide accumulated values placed in each of the f power bins by n, to yield an average power in each bin, and (b) display in the histogram, the average power in each bin.

6. The apparatus of claim 4, wherein the machine readable code is further operable to, in (viii), identify those bins in the histogram that have an event count above a given threshold and an average power.

7. The apparatus of claim 1, wherein the source of Gaussian noise includes an adjustable-power Gaussian noise generator and a Helmholz coil which is contained within the magnetic electromagnetic shielding, and which receives a selected noise output signal from the noise generator in a range 100 mV to 1 V.

8. The apparatus of claim 7, wherein the generator is designed to inject Gaussian noise into the sample at a frequency between DC and 2 kHz.

9. The apparatus of claim 1, wherein the detector is a second-derivative gradiometer which outputs a current signal, and a SQUID operatively connected to the gradiometer to convert the current signal to an amplified voltage signal.

10. The apparatus of claim 9, wherein the container is an attenuation tube having a sample-holding region, a magnetic shielding cage surrounding the region, and a Faraday cage also surrounding the region, wherein the source of Gaussian noise includes a Gaussian noise generator and a Helmholz coil, wherein the Helmholtz coil is contained within the magnetic cage and the Faraday cage and receives a noise output signal from the noise generator, and wherein the apparatus further includes, for use in removing stationary noise components, a signal inverter operatively connected to the noise generator and to the SQUID, for receiving Gaussian noise from the noise generator and outputting into the SQUID, Gaussian noise in inverted form with respect to the Gaussian noise injected to the sample.

11. A method for interrogating a sample that exhibits low-frequency molecular motion, comprising:

placing the sample in a container having both magnetic and electromagnetic shielding,

(a) injecting Gaussian noise into the sample at a selected noise amplitude;

(b) recording an electromagnetic time-domain signal composed of sample source radiation superimposed on the injected Gaussian noise,

(c) generating a spectral plot that contains, at a selected power setting of the Gaussian noise source, low-frequency, sample-dependent spectral components characteristic of the sample in a selected frequency range between 100 and 50 kHz, and

(d) repeating (a)-(c) at different selected noise amplitudes until a plot showing a maximum or near maximum number of spectral components characteristic of the sample is generated.

12. The method of claim 11, wherein the generating includes (i) calculating a series of Fourier spectra of the time-domain signal over each of a plurality of defined time periods, in a selected frequency range between 100 Hz and 50 kHz, and (ii) averaging the Fourier spectra.

13. The method of claim 12, wherein the calculating includes:

(i) storing a time-domain signal of the sample over a sample-duration time T;

(ii) selecting a sampling rate F for sampling the time-domain signal, where F* T is a total sample count S, F is approximately twice a frequency domain resolution f of a Real Fast Fourier Transform of the time-domain signal sampled at the sampling rate F, and S>f * n, where n is at least 10,

(iii) selecting S/n samples from the stored time-domain signal and performing a Real Fast Fourier Transform (RFFT) on the selected samples to produce an RFFT signal,

(iv) normalizing the RFFT signal and calculating an average power for the RFFT signal,

(v) placing an event count in each of f selected-frequency event bins where a measured power at a corresponding selected frequency > average power * ε, where 0< ε<1 and is chosen such that a total number of counts placed in an event bin is between about 20-50% of a maximum possible bin count in that bin,

(vi) repeating (iii) through (v), and

(viii) generating a histogram that shows, for each event bin f over a selected frequency range, a number of event counts in each bin.

14. The method of claim 13, which further includes, in (iv) placing the normalized power value from the RFFT signal in f corresponding-frequency power

bins, and in (viii): (a) dividing accumulated values placed in each of the f power bins by n, to yield an average power in each bin, and (b) displaying on the histogram, the average power in each bin.

15. The method of claim 14, which further includes identifying those bins in the histogram that have an event count above a given threshold and an average power.

16. A method of characterizing spectral emission features of a sample material, over a selected frequency range R, comprising:

selecting S/n samples from a time-domain signal and performing a Fast Fourier Transform (FFT) on the samples to produce an FFT signal, wherein F is a sampling rate for sampling the time-domain signal, where F* T is a total sample count S, F is greater than a frequency domain resolution f of the FFT of the time-domain signal sampled at the sampling rate F, and S>f * n, where n is at least 5;

calculating an average power for the FFT signal,

placing an event count in each of f selected-frequency event bins where the measured power at the corresponding selected frequency > average power * ε, where 0< ε<1 and is chosen such that the total number of counts placed in an event bin is between about 20-50% of maximum possible bin counts in that bin; and

generating a display that shows, for each event bin f over a selected frequency range, a number of event counts in each bin.

17. The method of claim 16, which further includes normalizing the FFT signal before calculating the average power, placing the normalized power value from the FFT in f corresponding-frequency power bins, dividing accumulated values placed in each of the f power bins by n to yield an average power in each bin, and displaying on a histogram the average power in each bin.

18. The method of claim 17, which further includes identifying those bins in the histogram that have an event count above a given threshold and an average power.

19. The method of claim 18, wherein R, expressed in Hz, is approximately equal to f, and the sample rate F, expressed in samples/second, is approximately 2f.

20. The method of claim 19, wherein the method detects low-frequency emission events related to molecular emissions in a sample, and wherein R includes at least the frequency range of 100 Hz to 5 kHz.

21. The method of claim 16, further comprising normalizing the FFT signal before calculating the average power, and wherein the FFT is a Real Fast Fourier Transform.

22. The method of claim 16, further comprising before, selecting, storing a time-domain signal of the sample over a sample-duration time T;

23. The method of claim 16, further comprising repeating the selecting, calculating and placing, before generating the display.

24. A low-frequency spectral signature associated with a material of interest comprising:

a list of frequency components in the DC-50 kHz frequency range that are generated by the method of claim 16.

25. The spectral signature of claim 24, wherein the frequencies in the list are identified from a histogram of a number of sample-dependent stochastic events occurring at each of a plurality of spectral increments within a selected frequency range between DC and 50 kHz.

26. An apparatus for detecting molecular signals from a sample, wherein the sample acts as a signal source, the apparatus comprising:

means for detecting electromagnetic emissions positioned near to the sample;

a Super Conducting Quantum Interference Device electrically connected to the means for detecting, wherein the Super Conducting Quantum Interference Device is positioned within a means for cryogenically cooling;

noise generation means for surrounding the signal source and the means for detecting signals with structured or uniform noise;

means for electromagnetically shielding the signal source, means for detecting, and Super Conducting Quantum Interference Device from external electromagnetic radiation, and wherein the means for electromagnetically shielding is positioned exterior to the means for cryogenically cooling;

means for controlling the Super Conducting Quantum Interference Device; and

means for observing the signal detected by the means for detecting electromagnetic emissions.

27. The apparatus of claim 26, further comprising tube means for vertically receiving the signal source therein, wherein the tube means provides at least 2 kHz of low pass filtering.

28. The apparatus of claim 26, further comprising automatic loading means for automatically and vertically positioning the signal source within the apparatus.

29. The apparatus of claim 26, further comprising superconducting lead shielding that at least partially encloses the signal source and means for detecting.

30. The apparatus of claim 26 wherein the means for detecting includes a second derivative gradiometer.

31. A computer-readable medium whose contents cause at least one data processing device to perform a method to display data representing electromagnetic emissions from a sample, the method comprising:

receiving a sample signal that has been produced by applying noise to a sample within a magnetically shielded detection apparatus, wherein a combination of the noise with an electromagnetic signal emitted by the sample takes on a different characteristic than the noise through stochastic resonance, and wherein the magnetically shielded detection apparatus includes therein a Super Conducting Quantum Interference Device electrically connected to at least one electromagnetic emission detection coil;

applying a Fast Fourier Transform to the sample signal; and

displaying, via a graphical user interface, the sample signal, wherein the sample signal is displayed as a series of peaks at select frequencies, wherein the peaks are substantially greater than other peaks in the sample signal, and wherein at least some of the other peaks represent the noise.

32. The computer-readable medium of claim 31 wherein the computer-readable medium is a memory of the data processing device.

33. The computer-readable medium of claim 31 wherein the computer-readable medium is a logical node in a computer network receiving the contents.

34. The computer-readable medium of claim 31 wherein the computer-readable medium is a computer-readable disk.

35. The computer-readable medium of claim 31 wherein the computer-readable medium is a data transmission medium carrying a generated data signal containing the contents.

36. The computer-readable medium of claim 31 wherein the computer-readable medium is a memory of a computer system.

37. An apparatus for detecting molecular signals from a sample, wherein the sample acts as a signal source, the apparatus comprising:

an electromagnetic emissions detector positioned near to the sample for detecting an emissions signal from the signal source;

a Super Conducting Quantum Interference Device (SQUID) electrically connected to the electromagnetic emissions detector, wherein the Super Conducting Quantum Interference Device is cryogenically cooled;

a noise canceling component;

a noise generator for providing structured or uniform noise to the emissions signals from the signal source, and for providing an inverted version of the noise to the noise canceling component;

electromagnetic shielding configured to shield the signal source, electromagnetic emissions detector, and Super Conducting Quantum Interference Device from external electromagnetic radiation;

a controller for controlling the Super Conducting Quantum Interference Device; and

an output port for outputting an amplified emissions signal, wherein the amplified emissions signal represents amplification of the signal source signal, through stochastic resonance, by the noise.

38. The apparatus of claim 37 wherein the noise canceling component is .positioned between the electromagnetic emissions detector and an input to the SQUID.

39. The apparatus of claim 37 wherein the noise canceling component is .positioned between the electromagnetic emissions detector and an output to the SQUID.

40. The apparatus of claim 37 wherein the noise generator includes first and second noise generating components, and noise canceling component includes first and second noise canceling components, the wherein the first noise canceling

component is positioned between the electromagnetic emissions detector and an input to the SQUID and is coupled to the first noise generator, and wherein the second noise canceling component is positioned at an output of the SQUID and is coupled to the second noise generator.

41. The apparatus of claim 37 wherein the noise generator provides a series of random values from a random number generator, and wherein the noise canceling component subtracts the series of random values from the amplified emissions signal.